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Prioritization Of Risks In Bicycle Supply Chain Using Multi Criteria Decision Making

S Hariharan[1], M Rajmohan[2]

[1]Research Scholar, Department of Industrial Engineering, CEG, Anna University, Chennai.

[2]Associate Professor, Department of Industrial Engineering, CEG, Anna University, Chennai.

Abstract- *Recent supply chain management optimization practices, while reducing costs and leaning inventory levels, have left companies with unprecedented levels of risk. Many companies have recognized this and are now undertaking supply chain risk management programs. This work deals with the application of Multi Criteria Decision Making (MCDM) techniques such as Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Situation (TOPSIS) and Fuzzy Analytic Hierarchy Process (FAHP) for prioritization of eight supply chain risks identified through literature and the expert opinion for a bicycle manufacturing company. A comparative analysis to know the certainty of decision making is done between AHP, TOPSIS and FAHP. The usefulness of these multi criteria decision making for this case study indicates that it can be applied to assist decision makers in prioritizing the risks in the supply chain.*

Keywords: Supply chain Management, Risk Management, AHP, TOPSIS, FAHP

I INTRODUCTION

In today's world of globalization, it is very difficult to build strong supply chains to gain advantage over their competitors to offer better value to customers. Even-though, careful attention is paid by the organizations in designing the supply chain network, often the designed supply chains are facing critical risks due to complex and dynamic activities. A supply chain can briefly be described as a network of all the individual enterprises that collaborate to produce a product to satisfy the customer needs. The objective of the supply chain is to support the flow of material, information and knowledge from the original supplier through multiple production and logistics operations to the ultimate consumer. According to Kajuter [7], Supply Chain Risk Management (SCRM) is responsible for the implementation of collaborative and structured approach to manage both every day and exceptional risks in the supply chain with the objective of reducing vulnerability and ensuring the achievement of the supply chain goals. Supply chain risk management seeks to establish mitigate and contingent strategies for how to deal with the risks and their potential impact on the supply chain. For this the first step is to identify and prioritize the critical risk factors. The objective of this study is to identify various risks in the bicycle supply chain and rank them using different Multi Criteria Decision Making (MCDM) techniques.

II LITERATURE REVIEW

This section deals briefly the review of literature related to risks in supply chain and Multi criteria Decision Making (MCDM) techniques which support the decision-makers (DMs) in evaluating a set of alternatives. Depending upon the situations, criteria have varying importance and there is a need to weigh them.

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A. Supply Chain Risk

Enkel et al [3] explained diverse risk management, a comprehensive risk management method will minimize various inherent risks in customer integration with company's examples. Vanany et al [19] surveyed supply chain risk management (SCRM) related literature for the period 2000 to 2007. The author analyzed those papers and classified SCRM into five categories. They also looked at the papers in terms of the industry sectors, the types of risks, the risk management process or strategies addressed, and the unit of analysis. Aundhe and Mathew [1] explained the effect of risks due to offshore IT outsourcing using grounded theory. The key area that contributing the risks according to them were nature of contract, nature of client and relationship maturity. Salunke et al [14] identified the risks involved in the reverse supply chain using survey. After the analysis the key risks are identified six sigma tools are used to mitigate the major risks in reverse supply chain.

Wu [21] analyzed the potential risk sources, and the characteristics of supply chain risk assessments in light with the existence of these risks. Yuen et al [23] proposed the Pre-ERM Model for supply chain risks at enterprise level. This classifies the enterprise risks under four pillars namely. Zhang and Li [25] suggested that more attention should be paid to the studies related to the formation mechanism of supply chain risk, models of default correlation and risk assessment in supply chain. Liu [9] used AHP to establish a risk assessment index system and also classified supply chain risk according to supply chain risk sources.

Mahalik[10] focused on the analytical frame work for analyzing uncertainty and risk in SCM and suggested a priority of risk using Analytic Network Process. Zandhessami and Savoji[24] explained risk management in supply chain by DEMATEL technique to analyze the severity of risks relating to each other in supply chain. The purpose of Tang and Musa [17] work is to concentrate on the development of research in SCRM. Related journals in the fields of supply chain has been reviewed, classified the potential risks and also to identified some research gaps.

To manage integrated supply chain information and forecast the risks, Li sha and Gu[8] designed the base functions for the early warning system according to its desires. Feng et al [4] gave a framework for mitigating disruptions in the supply chain. The work analyzes the strategies for dealing with disruption risks and provides directions for future research in the supply chain risk management. Vilko et al [20] assessed the information exchange and its risks in a supply chain. The authors investigated the different supply chain actors in a systematic way and concluded that control and visibility over the supply chain is dependent on cognitive barriers and internal organizational factors. The authors also states that risk management practices also dependent upon contingent factors that drive changes in supply chains.

Srinivasan et al [16] studied the relationship between partnership quality of buyer supplier and supply chain performance through a survey, due to supply, demand and environment risks. Yang et al [22] developed a comprehensive quantitative risk evaluation and mitigation model in global supply chains. The author identified four risks including supply, operational, demand and financial risks and modeled as probabilistic distributions of the outcome. Heckmann[5] reviewed the prevailing quantitative methods for Supply chain risk Management. This research helps in defining the Supply chain related risks and its measurement.

B. Multi Criteria Decision Making

Opricovic and Tzeng[11]uses different normalization methods in VIKOR and TOPSIS to study the different effects due to normalization with a numerical illustration. Vaidya and Kumar [18]gives an extended overview about the applications of AHP over the years and its growth in different fields referring almost 150 various reputed journals. Jahanshahloo et al [6] proposed new method for DMUs ranking using TOPSIS with interval data. Ramkumar et al [13] proposed a model for selection of TPLs network with an objective to create a favorable environment for improving coordination and integration using AHP and TOPSIS approach. A comparative analysis on decision-making certainty between the classical AHP and TOPSIS approach were also discussed.

Azadeh et al [2] presented a robust decision-making methodology based on Fuzzy Analytical Hierarchy Process (FAHP) for evaluating and selecting the appropriate software package. The FAHP is used to evaluate existing alternatives based on the proposed criteria for choosing the proper simulation software. Pires et al [12] had done a study to integrate the AHP and TOPSIS for alternative screening and ranking to help decision makers in a Portuguese waste management system. Zhang et al [26] analyzed the factors of supply risks in a systematic way and constructed the framework for calculating supply risk assessment index using hybrid weighting method and AHP.

One of the greatest challenges of supply chain is the uncertainty associated within it. This uncertainty allows room for numerous risks in the supply chain which poses challenge for forecasting and planning products. In order to improve the supply chain, a thorough analysis of risks and the means to minimize risks must be given permanent attention. This work mainly focus on identification, and prioritization of risk related to bicycle manufacturing supply chain.

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III METHODOLOGY

This section explains the methodology followed in this work to identify the critical risks in the bicycle supply chain. MCDM techniques support the decision-makers (DMs) in evaluating a set of alternatives. In MCDM, a problem is affected by several conflicting factors in selection, for which a manager must analyze the tradeoff among the several criteria. The Analytic Hierarchy Process (AHP) is a structured technique for dealing with complex decisions. AHP helps decision makers to find one that best suits their goal and their understanding of the problem. Analytic Hierarchy Process (AHP) is one of the most widely used tool since its invention, has been a tool at the hands of decision makers and researchers. TOPSIS (Technique for order preference by similarity to an ideal solution) is being used by several practitioners and researchers for solving various MCDM. TOPSIS approach is based on an aggregating function representing closeness to the reference point. The basic principle is that the chosen alternative should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution.

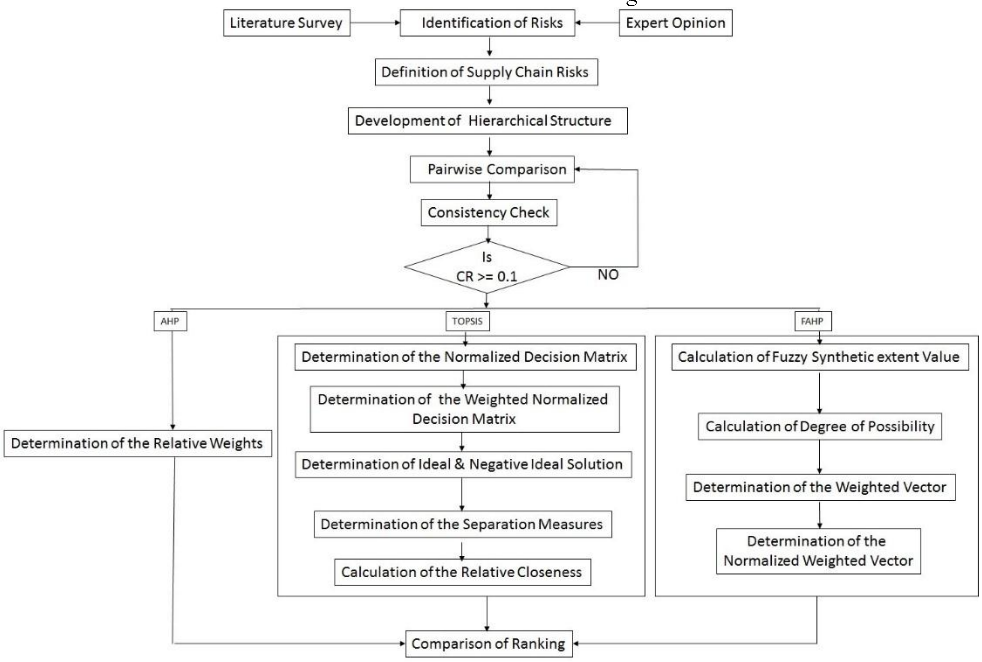

Figure 1: Schematic Diagram for Prioritizing the Supply Chain Risk

The fuzzy AHP technique can be viewed as an advanced analytical method developed from the traditional AHP. Decision makers judgments, fuzziness and vagueness existing in many decision-making problems may contribute to the imprecise judgments of decision makers in conventional AHP approaches. The extension of Saatys theory, have provided evidence that fuzzy AHP shows relatively more sufficient description of these kind of decision making processes compared to the traditional AHP methods.

Figure 1 shows the sequence of steps to be followed in prioritizing the critical risks in the bicycle supply chain.

IV CASE STUDY

The developed model is applied to a bicycle manufacturing company located in southern part of India. A supply chain of particular brand is selected for implementation of the methodology shows in figure 1. In this case, eight risks in the supply chain are considered and prioritized.

A. Prioritization Using AHP

This section provides the steps needed to calculate the priority value to rank the supply chain risk using AHP for the case study considered.

1. Define Decision Criteria

Eight risks namely Supplier, Storage, Process, Demand, Information, Transportation, Finance and Environment were identified as the relevant risks for this case through literature and expert opinion. The definition of each risk is given below.

1. Supply Risk(SU) - All issues with the movement of materials into an organization, including sources, supplymarket conditions, constraints, limited availability, supplier reliability, lead times, material costs, delays, etc.,

2. Storage Risk(ST) - Lack of care in maintaining quality, space lacking for storage.
3. Process Risk(PR) - Risks from product features, product mix, range, volumes, materials used and standardization.
4. Demand Risk(DE) - All aspects of customer demand, such as level of demand, variability, alternative products, competition and patterns of change.
5. Information Risk(IN) - Includes the availability of data, data transfer, accuracy, reliability, security of systems.
6. Transportation Risk(TR) - Movements of materials, including risks to the infrastructure, vehicles, facilities and loads.
7. Finance Risk(FI) - all money transactions, including payments, prices, costs, sources of funds, profit and general financial performance.
8. Environment Risk(EN) - Risks that are external to the supply chain.

2. Structuring the Hierarchical Model

This step involves building the AHP hierarchy model. Figure 2 shows hierarchy for this problem considered. The developed Hierarchy structure contains two levels: the goal and the risks.

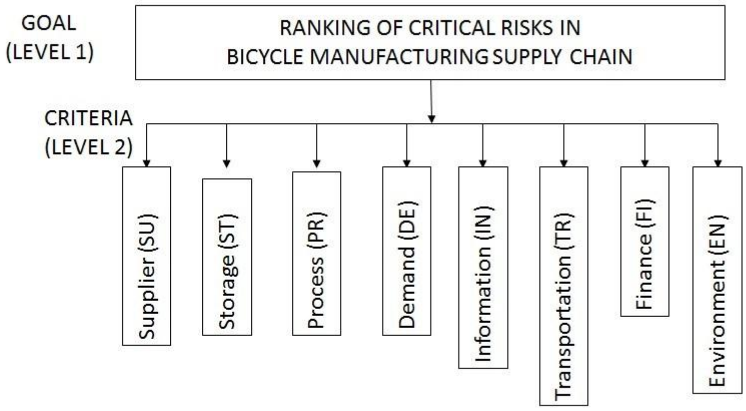

Figure 2: Hierarchy Structure for Prioritizing Supply Chain Risks

3. Pairwise Comparison

This step involves pairwise comparison of risks. Structured interview consisting of eight supply chain risks is used to collect the pair-wise comparison judgments from all evaluation team members. The function of the pairwise comparisons is to find the relative importance of the risks which is rated by the nine-point scale proposed by Saaty[15], as shown in Table 1. After obtaining the pairwise judgments, the next step is the computation of a vector of priorities or weighting of elements in the matrix.

Table 1
Relative Importance of the risks

Verbal judgment or preference Numerical	Rating
Extremely preferred	9
Very strongly preferred	7
Strongly preferred	5
Moderately preferred	3
Equally preferred	1
Intermediate values between two adjacent judgments (when compromise is needed)	2,4,6 and 8

4. Consistency Check

The consistency ratio (CR) is used to determine and justify the inconsistency in the pair-wise comparison made by the respondents. Based on Saaty's[15], empirical suggestion that a CR = 0.10 is acceptable. Table 2 shows the pair wise comparison of criteria. From the pair wise matrix, weighted sum vector and λ max values are calculated.

For calculating CR, equation (1) is used.

$$CI = \frac{\lambda \max - n}{n-1} \quad (1)$$

Where, n is the number of criteria compared and RI is the index from standard table for the corresponding value of n. Here RI = 1.41

$$CR = \frac{CI}{RI} \quad (2)$$

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Table 2
Pairwise Comparison Matrix of Main Criteria

Risks	SU	ST	PR	DE	IN	TR	FI	EN
SU	1	4	2	3	2	3	3	5
ST	0.25	1	0.33	0.33	0.5	0.5	0.5	0.33
PR	0.5	3	1	3	4	3	3	5
DE	0.33	3	0.33	1	2	2	3	2
IN	0.5	2	0.25	0.5	1	0.25	0.5	0.5
TR	0.33	2	0.33	0.5	4	1	3	4
FI	0.33	2	0.33	0.33	2	0.33	1	2
EN	0.2	3	0.2	0.5	2	0.25	0.5	1
Sum	3.44	20	4.77	9.16	17.5	10.33	14.5	19.83

λ max value found to be 8.83 and the CI value is computed as 0.119 using equation (1). From these values, CR value is calculated as 0.08 using equation (2) which is lesser than 0.1. So there exists consistency. This shows the judgment given by the respondents are consistent.

5. Determination of the Relative Weight

The relative weight of each risks is calculated by the row sum of the normalized pairwise comparison matrix. The result of prioritized risks and its weights are shown in Table 3.

Table 3
Priority Weights for Main Criteria with Rank

Risks	Local Weight	Rank
SU	0.26	1
ST	0.04	8
PR	0.23	2
DE	0.13	4
IN	0.06	7
TR	0.13	3
FI	0.08	5
EN	0.07	6

B. Prioritization Using TOPSIS

The following steps are followed to calculate weightage for prioritizing the supply chain risk for the case study considered using TOPSIS.

1. Formulating Normalized Decision Matrix

The normalized value R_{ij} is calculated using the equation (3).

$$R_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}}, i = 1,2,....., m; \; j = 1,2,...., n. \quad (3)$$

By using the values given in Table 2, the normalized value (R_{ij}) is calculated using equation (3) and the results are shown in Table 4.

1. Weighted Normalized Decision Matrix

The weighted normalized decision matrix Table 5 is obtained using equation (4).

$$V_{ij} = W_i * R_{ij}, \; j = 1,2,...., J; i = 1,2,...., n \quad (4)$$

Where, W_i- Weight of the i^{th}criterion, $\Sigma^{m}_{i=1} W_i = 1$

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Table 4
Normalized Matrix

Risks	SU	ST	PR	DE	IN	TR	FI	EN
SU	0.0100	0.0402	0.0201	0.0301	0.0201	0.0301	0.0301	0.0502
ST	0.0025	0.0100	0.0033	0.0033	0.0050	0.0050	0.0050	0.0033
PR	0.0050	0.0301	0.0100	0.0301	0.0402	0.0301	0.0301	0.0502
DE	0.0033	0.0301	0.0033	0.0100	0.0201	0.0201	0.0301	0.0201
IN	0.0050	0.0201	0.0025	0.0050	0.0100	0.0025	0.0050	0.0050
TR	0.0033	0.0201	0.0033	0.0050	0.0402	0.0100	0.0301	0.0402
FI	0.0033	0.0201	0.0033	0.0033	0.0201	0.0033	0.0100	0.0201
EN	0.0020	0.0301	0.0020	0.0050	0.0201	0.0025	0.0050	0.0100

Table 5
Weighted Normalized Matrix

Risks	SU	ST	PR	DE	IN	TR	FI	EN
SU	0.0026	0.0016	0.0046	0.0039	0.0012	0.0039	0.0024	0.0035
ST	0.0007	0.0004	0.0008	0.0004	0.0003	0.0007	0.0004	0.0002
PR	0.0013	0.0012	0.0023	0.0039	0.0024	0.0039	0.0024	0.0035
DE	0.0009	0.0012	0.0008	0.0013	0.0012	0.0026	0.0024	0.0014
IN	0.0013	0.0008	0.0006	0.0007	0.0006	0.0003	0.0004	0.0004
TR	0.0009	0.0008	0.0008	0.0007	0.0024	0.0013	0.0024	0.0028
FI	0.0009	0.0008	0.0008	0.0004	0.0012	0.0004	0.0008	0.0014
EN	0.0005	0.0012	0.0005	0.0007	0.0012	0.0003	0.0004	0.0007

2. *Determination of the Ideal and Negative Ideal Solution*

Ideal (A^*) and negative ideal (A^-) solutions are calculated using equations (5) and (6). Ideal Solution

$$A^* = \{V_1^*, V_2^*, \ldots, V_n^*\} \tag{5}$$

$$= Max_j V_{ij} \text{ for all i}$$

Negative Ideal Solution

$$A^- = \{V_1^-, V_2^-, \ldots, V_n^-\} \tag{6}$$

$$= Min_j V_{ij} \text{ for all i}$$

The calculated Ideal and Negative Ideal Solutions and shown in column 2 and 3 of Table 6.

3. *Determination of the Separation Measures From Ideal and Negative Ideal Solutions*

The separation of each alternative from the ideal solution (D^*_j) is calculated using equation (7) and separation of each alternative from the negative ideal solution (D^-_j) is calculated using equation (8). The computed values are given in column 4 and 5 in Table 6.

$$D_j^* = \sqrt{\left\{\sum_{i=1}^{n} \left(V_{ij} - V_i^*\right)^2\right\}}, \; j = 1,2,\ldots..J \tag{7}$$

$$D_j^- = \sqrt{\left\{\sum_{i=1}^{n} \left(V_{ij} - V_i^-\right)^2\right\}}, \; j = 1,2,\ldots J \tag{8}$$

4. Calculation of Relative Closeness to Ideal Solution

Relative closeness to the ideal solution (C_i^*) gives the score of each alternative. The relative closeness of the alternative with respect to A^* is given by equation (9).

$$C_j^* = \frac{D_j^-}{\left(D_j^* + D_j^-\right)}, \; j = 1,2,\ldots.J \tag{9}$$

Relative closeness to the ideal solution is shown in the column 6 of Table 6 This gives the score for each supply chain risk.

Table 6
Separation Measure and Relative Closeness

Risks	A^*	A^-	D^*	D^-	C^*	Rank
SU	0.0026	0.0005	0.0012	0.0080	0.868878	1
ST	0.0016	0.0004	0.0079	0.0005	0.055361	8
PR	0.0046	0.0005	0.0027	0.0070	0.722828	2
DE	0.0039	0.0004	0.0057	0.0036	0.387934	4
IN	0.0024	0.0003	0.0077	0.0010	0.111761	7
TR	0.0039	0.0003	0.0060	0.0041	0.401968	3
FI	0.0024	0.0004	0.0072	0.0017	0.18746	5
EN	0.0035	0.0002	0.0077	0.0013	0.146596	6

C. Prioritization Using FAHP

The following steps are followed to obtain the rank the supply chain risk considered in the case using FAHP.

I Calculate Fuzzy Synthetic Extent Value

Table 7 shows the pairwise matrix for supply chain risk. The fuzzy synthetic extent value with respect to the i^{th}risk is defined by equation 10.

Table 7
Pairwise Comparison Matrix for FAHP

Risks	SU	ST	PR	DE	IN	TR	FI	EN
SU	1,1,1	3,4,5	1,2,3	2,3,4	1,2,3	2,3,4	2,3,4	4,5,6
ST	0.2,0.25,0.33	1,1,1	0.25,0.33,0.5	0.25,0.33,0.5	0.33,0.5,1	0.33,0.5,1	0.33,0.5,1	0.25,0.33,0.5
PR	0.33,0.5,1	2,3,4	1,1,1	2,3,4	3,4,5	2,3,4	2,3,4	4,5,6
DE	0.25,0.33,0.5	2,3,4	0.25,0.33,0.5	1,1,1	1,2,3	1,2,3	2,3,4	1,2,3
IN	0.33,0.5,1	1,2,3	0.2,0.25,0.33	0.33,0.5,1	1,1,1	0.2,0.25,0.33	0.33,0.5,1	0.33,0.5,1
TR	0.25,0.33,0.5	1,2,3	0.25,0.33,0.5	0.33,0.5,1	3,4,5	1,1,1	2,3,4	3,4,5
FI	0.25,0.33,0.5	1,2,3	0.25,0.33,0.5	0.25,0.33,0.5	1,2,3	0.25,0.33,0.5	1,1,1	1,2,3
EN	0.17,0.2,0.25	2,3,4	0.17,0.2,0.25	0.33,0.5,1	1,2,3	0.2,0.25,0.33	0.33,0.5,1	1,1,1

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} \qquad (10)$$

For Example,

$$S_1 = \frac{\sum SU_{ij}}{SUM}$$

$$= \frac{(16,23,30)}{135.33,99.567,68.55} = 0.118,\ 0.231,\ 0.437$$

Similarly for other risks ($S2, S3, \ldots, S8$) the Fuzzy Synthetic Value is calculated and are given in Table 8.

Table 8
Fuzzy Senthetic Extent Value

Risks	L	M	U
SU	0.118227	0.231001	0.085096
ST	0.021789	0.037663	0.085096
PR	0.12069	0.225979	0.423049
DE	0.062808	0.137261	0.27717
IN	0.027586	0.055239	0.126428
TR	0.080049	0.152327	0.291758
FI	0.036946	0.083696	0.175055
EN	0.038424	0.076833	0.158035

II Calculate Degree of Possibility of Each Pair

The degree of possibility of $M_2(l_2,m_2,u_2) >= M_1(l_1,m_1,u_1)$ is defined by equation (11) where x and y are the values on the axis of membership function of each risk.

$$V(M_2 >= M_1) = \sup[\min(M_x,\ M_y)] \qquad (11)$$

$y >= x$

This expression can be equivalently written by equation (12) given below:

$$V(M_2 \geq M_1) = \begin{cases} 1, if\ (m_2 \geq m_1) \\ 0, if\ (l_1 \geq u_2) \\ \dfrac{l_1 - u_2}{(m_2 - u_2)(m_1 - l_1)}, otherwise \end{cases} \quad (12)$$

Check the condition by comparing for two risk values S_1 and S_2 using equation (12), the values for S_1 compared with all S_i is [1,1,1,1,1,1,1] . Similarly for all the combinations the condition is verified using equation (11) and (12).

III Determination of Weighted Vector

The degree possibility for a convex fuzzy number to be greater than k convex fuzzy number M_i(i= 1,2,3,4, ,k) can be defined by $V(M >= M_1, M_2, M_3, \ldots\ldots, M_k) = \min V(M >= M_i), i = 1,2,3,\ldots.k$.

d'(A_i) = min V($S_i \geq S_k$) For k=1,2,3,……., n;k≠i. (13)

Then the weight vector is given by equation (14);

$$W' = (d'(A_1), d'(A_2), \ldots\ldots\ldots\ldots, d'(A_n))^T \quad (14)$$

Where A_i(i=1,2,3,……..,n)

Cal-culate the minimum of ($S_1 >= S_i$) using equation (13), min$V(S_1 >= S_2) = 1$ Similarly on comparing all S_i for all min value, W is obtained as W = [1, 0, 1, 0.63, 0.024, 1, 0.489, 0.355]

IV Determination of Normalized Weighted Vector

The normalized weight vector are obtained by equation (15).

$$W = (d(A_1), d(A_2), \ldots\ldots., d(A_n))^T, fori = 1,2,\ldots.,n \quad (15)$$

W (Normalized) = [0.22, 0, 0.22, 0.14, 0.005, 0.22, 0.11, 0.08]

Table 9

Priority Weights for Main Criteria with Rank using FAHP

Risks	Local Weight	Rank
SU	0.22	1
ST	0	8
PR	0.22	2
DE	0.14	4
IN	0.005	7
TR	0.22	3
FI	0.11	5
EN	0.08	6

Table 10

Comparison Of Priority Weights Of AHP, TOPSIS and FAHP

Sl.No	Risks	AHP	TOPSIS	FAHP	Rank
1	SU	0.26	0.8689	0.22	1
2	PR	0.23	0.7228	0.22	2
3	TR	0.13	0.4020	0.22	3
4	DE	0.13	0.3880	0.14	4
5	FI	0.08	0.1875	0.11	5
6	EN	0.07	0.1466	0.08	6
7	IN	0.06	0.1118	0.005	7
8	ST	0.04	0.0554	0	8

V RESULTS AND DISCUSSION

The weights obtained by AHP, TOPSIS and FAHP for the criteria are compared by calculating the gap between the adjacent prioritized criteria by each method which is discussed below.

Table 10 provides the weightages computed for eight supply chain risks considered by using AHP, TOPSIS and FAHP. From Table 10, it is observed that all the three methods considered provide the same ranking for the supply chain risks. Supply risk is identified as the most primary risk followed by process risk and the storage risk is ranked as the least important risk among the eight risk considered in this study. Also it is seen that there is no much different in weight obtained by AHP and FAHP where as there is a meaningful difference in weightages obtained by TOPSIS when compared to that of AHP and FAHP.

From Figure 3, it is clear that all the gap between adjacent prioritized criteria were clearly high for TOPSIS compared to AHP. Also by comparing AHP and FAHP there is no difference in the prioritization but considering the gap between adjacent prioritized criteria some vales are high for AHP and some are high for FAHP. Whereas all the gap between adjacent prioritized criteria were clearly high for TOPSIS compared to FAHP. For example, Figure 3 shows the gap between the adjacent ranks for the three techniques. The gap between rank 1 and 2 using AHP gives 0.03 and FAHP gives 0 were clearly less significant compared to the difference when using TOPSIS which gives 0.15. So it is clearly evident that considering the three MCDM techniques, TOPSIS gives more clear idea of ranking compared with AHP and FAHP in this case.

VI CONCLUSION AND FUTURE WORK

In current dynamic environment risk management became an extremely important activity in supply chain management.In this work, three MCDM techniques AHP, TOPSIS and FAHP were adopted to rank the critical supply chain risk for an bicycle manufacturing company. Eight important supply chain risks were identified as significant risk for the case considered. The result obtained from AHP, TOPSIS and FAHP were same. Supplier risk found to be the most important one and storage risk given the last priority. But TOPSIS technique gives more clear difference between the criteria. In future, for the same case other MCDM techniques like DEMATEL, Fuzzy TOPSIS can be applied to guide decision makers.

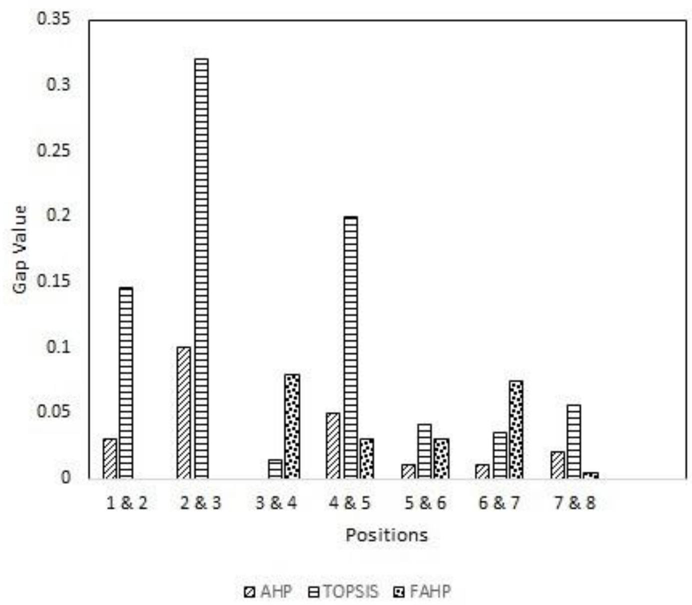

Figure 3: Gap Analysis

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